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"Paramagnetic and Diamagnetic Resonance of Conduction Electrons"

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27 July 1951.

/Note: The following report appeared in the regular Physics section of the thrice-monthly journal Doklady Akademii Nauk SSSR, Volume 81, No (1) December 1951), pages 765-6. It was submitted by academician L. D. Landau 10 October 1951./

As is well known, paramagnetic resonance is the name given to the phenommenon of the selective absorption of energy quanta of the radiofrequency field, which phenomenon is connected with the variations of the orientation of the elementary magnets (electron spins, nuclei, ions, atoms, etc) relative to the constant magnetic field H (1). An effect of such kind must obviously occur even for conduction electrons. The maximum of selective absorption corresponds here to the frequency

$$\nu_p = \frac{2\mu H}{h} = \frac{e H}{m c} \qquad (1)$$

where μ is the spin magnetic moment of an electron, e is the charge, and

m is the rest mass of the electron.

Besides this commonly known paramagnetic effect of conduction electrons we should expect the existence ~~and~~ another form of magnetic resonance, which we shall call diamagnetic resonance. This effect, up til now, apparently has not yet ~~been~~ described in the literature, must be directly connected with the diamagnetism of conduction electrons discovered by L. D. Landau (2).

Diamagnetism of conduction electrons is caused, as is well known, by the fact that during the presence of an external constant (permanent) magnetic field H the conduction electrons describe quantum orbits in the plane perpendicular to the direction of H.

In the case of perfectly free electrons of conduction the energy of these orbits will be

$$E_n = \frac{ehH}{mc}\left(n + \frac{1}{2}\right) \qquad (2)$$

where $n = 0, 1, 2, \ldots$

Thus the diamagnetic resonance of conduction electrons must be connected with the quantum transitions during which n changes by ± 1. In this case the maximum of diamagnetic resonanse must correspond to the frequency

$$\nu_\Delta = eH/mc \, . \qquad (3)$$

Thus for perfectly free electrons we must expect the existence of two theoretically different effects whose frequencies, however, coincide

$$\nu_p = \nu_\Delta$$

It is necessary to stress that paramagnetic resonance is caused by the component of the variable magnetic field which (i.e. component) is perpendicular to the direction of the constant field H, whereas ~~Moreover~~ the diamagnetic effect must be caused by the component of the variable magnetic field which (i.e. component) is parallel to H. This fact permits us to sepprate the effects from one another.

In the case of quasi-connected electrons the energy of the quantum orbits in a constant field H is determined in the first approximation by the following relation

$$E_n = \frac{e h H}{m^* c} \left(n + \frac{1}{2} \right) \qquad (4)$$

where m^* is the so-called "effective mass" of the conduction electrons. Consequently we have

$$\nu_\Delta = eH / m^* c \; ; \qquad (5)$$

whereas we have the maximum of paramagnetic resonance determined as before by expression (1).

Thus in this case we have $\nu_0 \neq \nu_\Delta$.

The magnetic resonance of conduction electrons has been observed up til now, as far as is known by the author, only in solutions of alkali metals in liquid ammonia (3,4). The paramagnetic resonance was observed under special conditions since the authors (3,4) did not foresee the possibility of the existence of diamagnetic resonance. Actually they observed only paramagnetic effects at the frequency ν_p.

The discovery of the diamagnetic resonance of conduction electrons is of interest, in the present author's opinion, to physicists studying metals and semiconductors, since the experimental measurement of the frequency ν would permit us immediately to determine the numerical values of the "effective mass" m^* for the various electron conductors even for diverse conditions.

In conclusion I wish to thank K. Ter-Martirosyan for his critical perusal of the problems expounded here.

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